Growth and Phenomenology of Phytoplankton Thins Layers in the Gulf of Maine

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LONG-TERM GOALS

Our overarching long-term goal is to understand what controls phytoplankton distribution, optical properties and production in the coastal ocean. Our project-specific goals are to understand the mechanisms responsible for the creation, maintenance and demise of subsurface phytoplankton layers in the Gulf of Maine; to decrease uncertainty in interpretation of chlorophyll *a* fluorescence as an estimator of phytoplankton biomass by better understanding daytime fluorescence quenching; and to determine the vertical distribution of toxigenic species of *Alexandrium* in the Gulf of Maine.

OBJECTIVES

The specific objectives of the past year's work were: 1) to continue to analyze data from two cruises in 2005 and 2006 in the Gulf of Maine to better understand how the subsurface distributions of phytoplankton and suspended particles are controlled by light, nitrate and density structure over a broad range of hydrographic conditions; 2) to improve analysis of nitrate concentrations derived from *in situ* UV absorption spectra with ISUS; 3) to continue to analyze data from optically-instrumented gliders deployed in Gulf of Maine; 4) to confirm diel and vertical patterns in phytoplankton UV absorption coefficients; 5) to analyze patterns in photoinhibition of variable fluorescence and *in situ* chlorophyll *a* fluorescence; and 6) to continue to analyze distributions of *Alexandrium* species in the Gulf of Maine.

APPROACH

In the 2005 field program we successfully located phytoplankton thin layers in the Gulf of Maine, but we were not able to stay within a single layer. In the 2006 field year we broadened out approach to a more general study of the vertical structure of subsurface phytoplankton layers in the Gulf of Maine,

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and carried out a survey program in order to encounter a wide range of optical and hydrographic conditions within a relatively restricted geographic area. On the order of 150 profiles were taken of temperature, salinity, chlorophyll *a* and CDOM fluorescence, beam c, optical backscattering, dissolved oxygen, and PAR; approximately 100 profiles included continuous nitrate measurements (Satlantic ISUS). At a number of depths and stations, discrete water samples were collected for chlorophyll, phytoplankton absorption, variable fluorescence, nutrients and samples of *Alexandrium spp.* distributions; in addition *Alexandrium* samples were collected with a vertical pumping system. At the time of the 2006 cruise we also deployed a Slocum glider instrumented with a SBE CTD, Aanderaa optode, and two WET Labs Eco pucks (chlorophyll *a* and CDOM fluorescence; 3 wavelengths of backscattering).

WORK COMPLETED

In the past year we have focused on analyzing data from the 2006 cruise in the Gulf of Maine, completing fluorescence quenching experiments, confirming diel and vertical patterns in phytoplankton UV absorption coefficients, testing a Slocum glider with Satlantic radiometers, and completing analysis of distributions of *Alexandrium* species in the Gulf of Maine. In 2007 additional fieldwork was carried out from a small boat in Wilkinson Basin in the Gulf of Maine and in the Damariscotta River Estuary to continue studies of phytoplankton absorption, variable fluorescence, and fluorescence quenching. A brief glider mission was carried out in 2007 with a Slocum glider instrumented with Satlantic radiometers.

RESULTS

One major focus has been analysis of date from the 2006 cruise in the Gulf of Maine. Although we found relatively few "thin" layers, most of the summer water masses were highly stratified and almost all had well-defined subsurface phytoplankton layers. The only exception was a very well-mixed water mass in the Eastern Maine Coastal Current north of the Penobscot River discharge. We used the method of Twardowki et al. (2001) to characterize particle scattering as organic or mineral; high ratios of optical backscattering to beam c are indicative of minerals, while low ratios are characteristic of organic particles. In Figure 1 we use relative counts to display the bimodal distribution of the backscattering ratio. Most high ratios were found at depth, as expected for waters dominated by

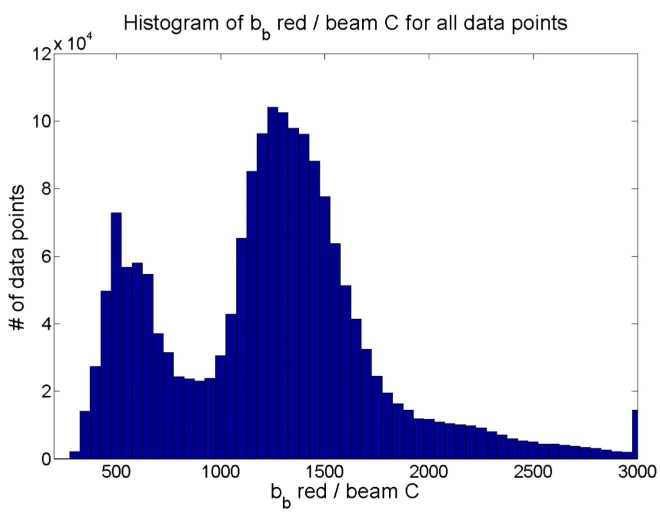

Figure 1. Relative ratios of optical backscattering-to-beam c in the Gulf of Maine.

resuspended sediments, and most low ratios were found in near-surface waters dominated by organic particles, with the exception of the Eastern Maine Coastal Current (Fig. 2). Ratios of fluorescence-to-beam c could then be used in near-surface waters dominated by organic particlew to assess phytoplankton photoadapted state – fluorescence quenched, high-light or low-light adapted. In 60% of all well-defined peaks, the beam c maxima was within +/-0.5 m of the fluorescence maxima. Subsurface oxygen maxima were typically observed close to the beam c maxima, indicating that phytoplankton in the subsurface layers were actively growing.

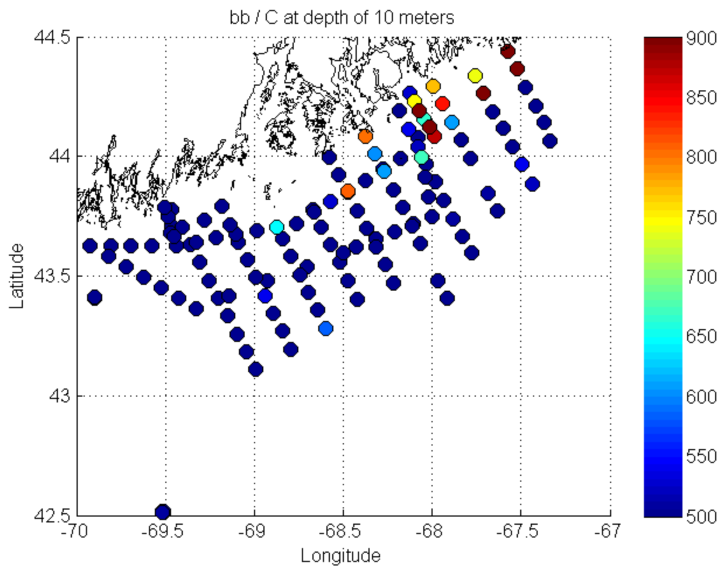

Figure 2. Distribution of relative ratios of optical backscattering-to-beam c in the Gulf of Maine.

During the 2006 cruise, we successfully collected a number of continuous profiles of nitrate with the ISUS and analyzed over 1,000 wet chemistry nitrate samples for its calibration. This year, in collaboration with Ken Johnson of MBARI, we were able to tune ISUS calibrations (Fig. 3), thereby improving the accuracy of the nitrate profiles. We are using profile data to analyze vertical gradients in phytoplankton and nitrate to understand the role of nitrate flux in controlling the magnitude and maintenance of the subsurface layers.

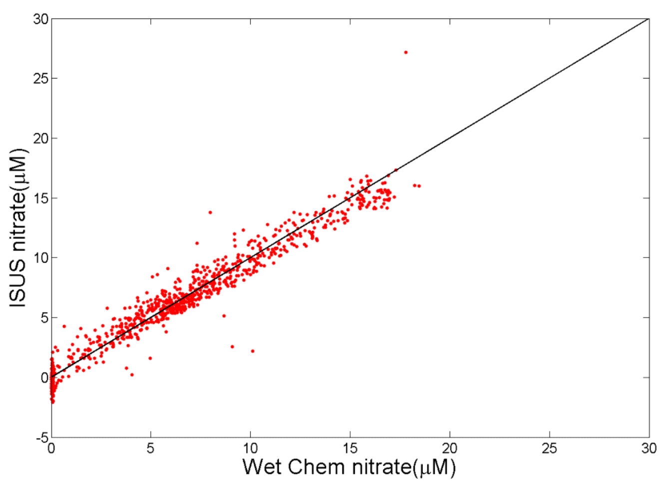

Figure 3. Distribution of relative ratios of optical backscattering-to-beam c in the Gulf of Maine.

Data from previous years were analyzed and new experiments were completed to study chlorophyll *a* fluorescence quenching and diel variability in absorption by MMA-like pigments. Both daytime fluorescence quenching with in situ fluoremeters and variable fluorescence (Fv/Fm) with Satlantic FIRe show similar patterns in response to ambient light, i.e., decreases with increases in light (Fig. 4).

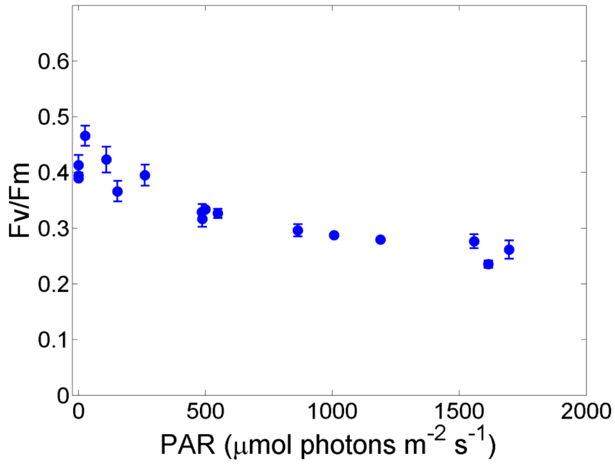

Figure 4. Variable fluorescence (Fv/Fm) as a function of irradiance.

These results suggest that variable fluorescence measurements on autonomous platforms would be a useful tool for determining if chlorophyll is quenched and therefore help reduce biases in estimates of phytoplankton biomass from fluorescence. The time course of recovery of fluorescence and variable fluorescence shows that a small amount of light is essential for photosystem recovery (Fig. 5).

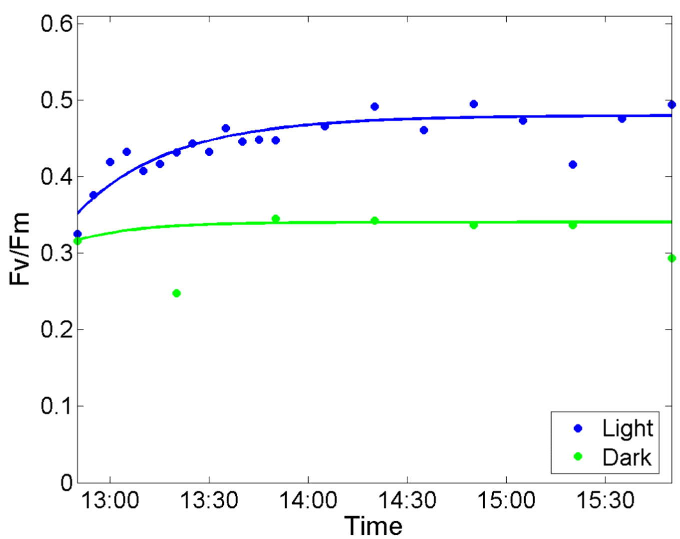

Figure 5. Light recovery of variable fluorescence (Fv/Fm); lack of recovery in complete darkness.

Last year strong diel patterns in UV-absorbing pigments were observed during a diel study in Wilkinson Basin in the Gulf of Maine. Absorption coefficients at 320 nm increased in the morning and then decreased throughout the afternoon, with the magnitude of absorption decreasing with depth (Figs. 6, 7). The diel plasticity of the UV absorption was unexpected and not previously reported in field studies. Observations this summer confirmed the phenomenon (Fig. 8). A Slocum glider instrumented with Satlantic radiometers was tested in the Gulf of Maine (Fig. 9). Analyzes of *Alexandrium* distributions show higher concentrations downstream of the Eastern Maine Coastal Current (Fig. 10).

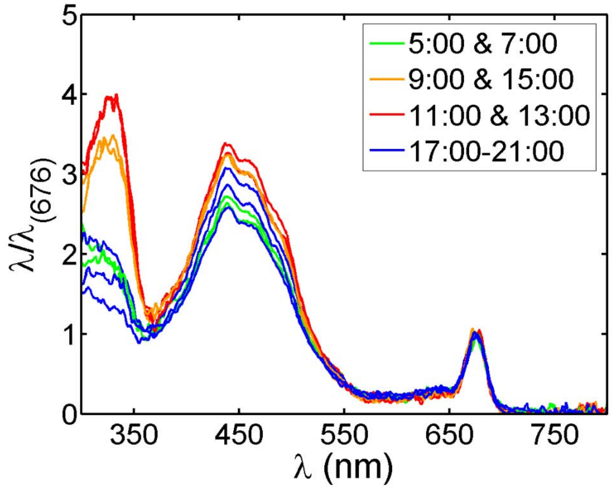

Figure 6. Absorption spectra of phytoplankton from 0 m, Wilkinson Basin, Gulf of Maine.

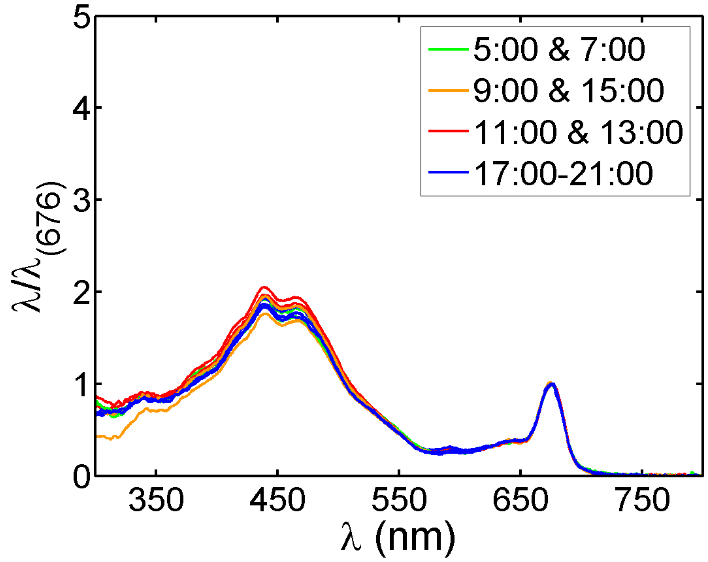

Figure 7. Absorption spectra of phytoplankton from 25 m, Wilkinson Basin, Gulf of Maine.

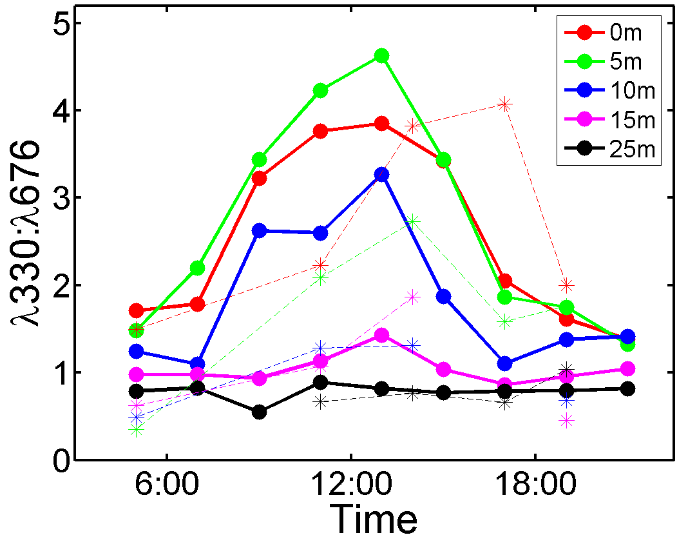

Figure 8. Ratio of absorption 330 to 676 nm five depths, Wilkinson Basin, Gulf of Maine; solid circles from 2006 and stars from 2007.

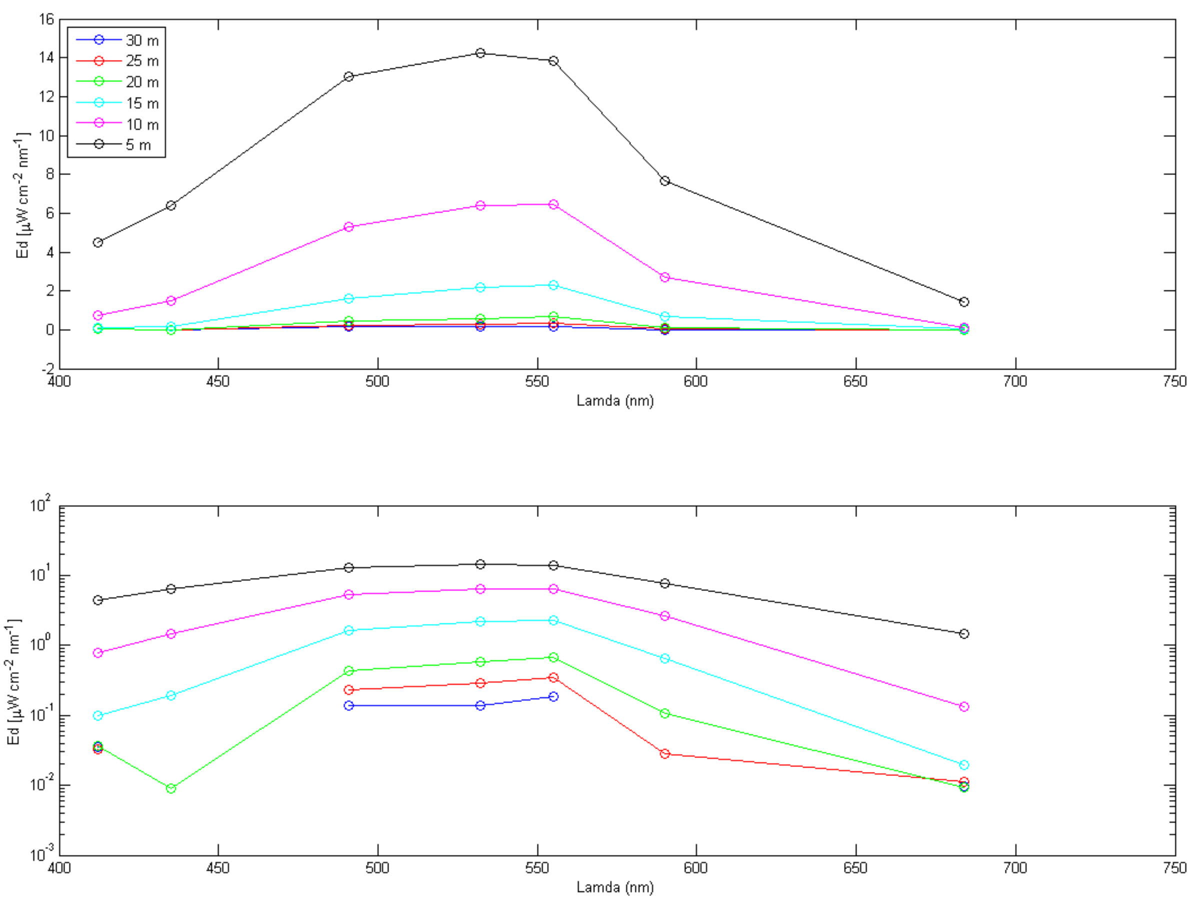

Figure 9. Irradiance spectra (Ed) from Slocum glider deployed in Gulf of Maine.

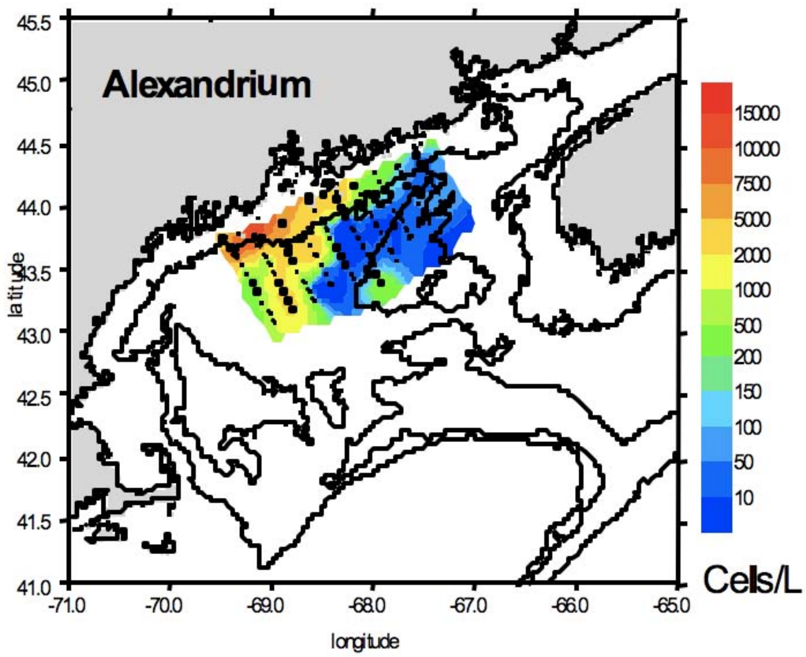

Figure 10. Distribution of Alexandrium spp. in June 2006.

IMPACT/APPLICATIONS

A better understanding of the interaction of hydrography, nutrients, and light in controling the subsuface distribution of phytoplankton is important to the Navy in its goal of predicting and understanding how biota affect the optical properties of operational importance to the Navy.

RELATED PROJECTS

The underwater glider was acquired under award N000140510412 to Perry, Townsend and colleagues, entitled "Acquisition of Underwater Gliders for Autonomous Sampling in the Gulf of Maine".

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